DUAL SINK VECTOR-BASED ROUTING PROTOCOL FOR UNDERWATER WIRELESS SENSOR NETWORK

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This dissertation is dedicated to my beloved parents

and my husband for his endless support and encouragement and

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ABSTRACT

Underwater wireless sensor networks (UWSNs) have become the seat of researchers' attention recently due to its proficiency to explore underwater areas and finding different applications for offshore exploration and ocean monitoring. One of the main objectives of each deployed underwater network is discovering the optimized path over sensor nodes to transmit the monitored data to onshore station. Data transmission consumes energy of each node, while energy is limited in UWSNs; energy efficiency is a challenge in underwater wireless sensor network. An available routing protocol which named vector based forwarding protocol (VBF) is enhanced. The main purpose of this routing protocol is balancing the energy consumption in UWSNs. Dual sinks vector based forwarding (DS–VBF) takes both residual energy and location information into consideration as a priority factor to discover an optimized routing path to save energy in underwater networks. The modified routing protocol employs dual sinks on the water surface that lead to improve network lifetime. According to deployment of dual sinks, packet delivery ratio and the average end to end delay also are enhanced. Based on our simulation results in comparison with VBF; average end to end delay reduced more than 80%, remaining energy increased 10%, and increment of packet reception ratio is about 70%.

ABSTRAK

Baru-baru Rangkaian pengesan tanpa wayar dasar laut(UWSNs) telah menjadi perhatian penyelidikan kerana tuntutan untuk meneroka bidang dasar laut dan mencari aplikasi yang berbeza untuk eksplorasi luar pesisir dan pengawasan pantai. Salah satu objektif utama setiap rangkaian dasar laut yang digunakan adalah mencari jalan yang lebih optimum bagi nod sensor untuk menghantar data pemantauan untuk stesen daratan. Penghantaran data menggunakan tenaga setiap nod, walaubagaimanapun tenaga adalah terhad dalam UWSNs; kecekapan tenaga adalah satu cabaran di dalam rangkaian pengesan tanpa wayar dasar laut. Bagi menangani cabaran ini, protocol halaan telah diting katkan yang dinamakan protokol penghantaran berasaskan vektor (VBF). Tujuan utama protokol halaan ialah mengimbangi penggunaan tenaga di UWSNs. Dwi benam penghantaran berasaskan vektor (DS-VBF) mengambil kedua-dua tenaga sisa dan maklumat lokasi sebagai faktor utama untuk mencari jalan laluan yang dioptimumkan untuk menjimatkan tenaga dalam rangkaian dasar laut. Protokol halaan diubahsuai menggunakan dwi-benam di permukaan airyang memperbaiki hayat rangkaian. Menurut penggunaan dwi-benam, nisbah penghantaran paket dan purata pengurangan lengahan kelewatan juga adalah dipertingkatkan. Berdasarkan keputusan simulasi dalam perbandingan dengan VBF; purata akhir untuk mengurangkan kelewatan didapati lebih daripada 80%, baki tenaga meningkat 10%, dan kenaikan nisbah penerimaan paket kira-kira 70%.

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LIST OF ABBREVIATIONS

2D	-	Two Dimensions
3D	-	Three Dimensions
AOA	-	Angle of Arrival
AUVs	-	Autonomous Underwater Vehicles
CPU	-	Central Processing Unit
CSMA	-	Carrier Sense Multiple Access
DBR	-	Depth Based Routing
DDD	-	Mobile Delay-Tolerant Approach
DFR	-	Directional Flooding-Based Routing
DS-VBF	-	Dual Sinks Vector Based Forwarding
DUCS	-	Distributed Underwater Clustering Scheme
FBR	-	Focused Beam Routing
H2-DAB	-	Hop-by-Hop Dynamic Based Routing
HH-VBF	-	Hop-by-Hop Vector-Based Forwarding
ICRP	-	Information-Carrying Routing Protocol
Multi Sink	-	Multi Sink Opportunistic Routing Protocol
Multipath-VS	-	Multi Path Virtual Sink Architecture
NS-2	-	Network Simulator Version Two
N-VBF	-	New Vector Based Forwarding
RAM	-	Random Access Memory
RF	-	Radio Frequency
RTS	-	Request To Send
SDVs	-	Small Delivery Vehicles
TCB	-	Temporary Cluster Based Routing
UASN	-	Underwater Acoustic Sensor Network
UWSNs	-	Underwater Wireless Sensor Networks

VBF	-	Vector Based Forwarding
VBVA	-	Vector Based Void Avoidance
WSNs	-	Wireless Sensor Networks

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless sensor networks (WSNs) have become the seat of researchers' attention recently due to its proficiency to explore a large number of unexplored areas such as underwater and underground areas. Because of the vital role of the ocean in the humanity's life like: 70% of the Earth is surface is water, the ocean is a significant resource to produce nutritious, sea and ocean are a means of transport, a considerable population of the world are living beside the sea or ocean. So it is obvious that every change in the Earth's water will effect on human life therefore more effort should be done to explore these areas (Bayrakdar *et al.*, 2011) According to mentioned reasons, underwater wireless sensor networks (UWSNs) were introduced to enable many discovering applications for example: pollution and environmental monitoring, climate recording, oceanographic data collection, offshore exploration, disaster prevention, tactical surveillance, seismic monitoring, etc.

Underwater wireless sensor networks consist of sensor nodes and vehicles which are designed to perform collaborative tasks to support mentioned application over a specified geographical area. Underwater sensors nodes and vehicles must be able to manage their operation by exchanging configuration, location, and movement updated information and to transfer sensed data to an onshore station over a wireless connection. As sensor network applications require long transmission distance, radio

waves propagate at long distance through the conductive sea water at extra low frequencies (30-300HZ) which requires large antennae and high transmission power. Due to the scattering properties of optical waves in water use of radio waves and optical waves are inefficient so it is widely recognized, acoustic communications are the best choice for the communicate medium in underwater networks (Pompili, 2007).

Before a network can be used it must be able to transfer sensed data from source to destination node, moreover due to the circumstances of water like 1. Water salinity, temperature and contaminants in water: the possibility of nodal failure caused by erosive is high and 2. Each node has transmitted range limitation that is received by a same sink through a network of nodes, appropriate routing algorithms are necessary to direct data in an optimized way, but various priorities should be determined to design a routing protocol algorithm.

In this work an algorithm to address energy efficiency in the underwater wireless sensor network is proposed. Several routing protocols have been introduced for underwater sensor networks in recent years that assumed all nodes static which is impossible based on current water therefore. This work intends to study different approaches to increase the packet delivery ratio and increase the lifetime of network by applying multi-sink protocols that assumes all the nodes are dynamic and know about the positions of all the other nodes and themselves (geographical routing protocol). Furthermore residual energy of each sensor node takes into consideration to make energy consumption equal in the network.

1.2 Problem Background

The most important objective of each network is routing. Routing protocols are designed to transmit monitored data from source (sensor node) to the destinations (surface sinks or station) via intermediate nodes. Due to the unique features of

underwater environments, presenting an efficient routing algorithm that provides networking demands is a critical challenge for researchers recently. The first routing protocol was a location based routing approach that has presented in 2006 by (Xie *et al.*, 2006) to handle the mobility of nodes in underwater and simulating 3D circumstance. On vector based forwarding routing protocol (VBF) all the data packet forwarded to the sink through on virtual pipe that is placed based on a vector from source node to the target node, in this protocol small number of nodes which are located in a virtually routing pipe are involved in forwarding data packets. All nodes have information about the position of entire network and themselves.

Multiple paths are provided to transmit data to the sink (destination) and if a node is close enough to the forwarding vector, it will forward the data packet otherwise this node will discard the packet. Although VBF is robust and dynamic and the data traffic is low but a limited number of nodes that have location priority participate in data transmission and consume their energy again and again. It may cause this specific node will die sooner and network will fail in a short time.

Moreover VBF is too sensitive to routing pipe; in order to solve this problem a new routing protocol presented by (Nicolaou *et al.*, 2007) named Hop-by-Hop Vector-Based Forwarding in 2007. The basic concept of routing vector in HH-VBF is similar to VBF however it forms the routing pipe in a hop-by-hop fashion from each intermediate forwarding node to the sink. Because of no use of single virtual pipe each node forwards packets based on its current location. In HH-VBF when a node receives a packet, it first holds the packet for some time, to compute its desirableness factor like VBF then the node with the smallest desirableness factor will send the packet. HH-VBF allows each node overhearing the duplicate packet transmissions to control the forwarding of this packet to the sink. By doing this, even in sparse networks; HH-VBF can find a data delivery path as long as there is an available node in the forwarding path.

Since each node forms a new routing pipe, this mechanism is not too sensitive to predefined routing pipe radius and the maximum pipe radius is the

transmission range and the packet delivery ratio enhances significantly. In this algorithm the end to end delay and consuming energy is high because each node overheard the duplicated data and wait for some time to select the best node to forward the data packet.

Afterwards Vector-Based Void Avoidance (VBVA) was presented by (Xie *et al.*, 2006) to address the routing void problem in mobile underwater sensor networks. VBVA is a vector-based protocol; whenever there is no void, it works in the same way as VBF. If a void occurs in network VBVA fulfills its vector-shift mechanism which tries to shift its forwarding vector to bypass the void. If the vector-shift mechanism fails, VBVA resorts its back-pressure mechanism to retreat the data packet back from the end paths. VBVA detects both convex and concave void only when needed and handles the void on demand and thus does not need to know network topology and void information in advance.

All the aforementioned protocols are robust and scalable, but the end-to-end delay is relative long so a new vector based forwarding protocol (N-VBF) was proposed by (Su *et al.*, 2010) to satisfy the requirement in low delay environment. This protocol brings forth a novel algorithm for node selection and packet forwarding, that is a vector based algorithm.

The selection process of forwarding node is exactly similar to VBF, just the structure of packet data is a little different from VBF that includes packet information (SP, FP, TP, PID, R, WIDTH), where SP is the source position, FP is the position of the forwarding position, TP is the target position, PID is the packet label, R and WIDTH is the node transmission range and the radius of the routing vector. When each node receives the packet and makes the decision, if node is eligible to forward the data it keeps data packet and check whether the SP and PID are in the node's ram, hence that means the node has already forwarded the data, the node will discard the packets; otherwise it continues to forward the packet and save it's SP and PID packet into the node RAM. Despite considering end to end delay in N-VBF

protocol, all the nodes consume extra energy to save data in their memory so this method is not energy efficient too.

1.3 Problem statement

Underwater sensor networks have received growing interest recently. Among many challenging issues in this area, routing is one of the fundamental networking problems to address, so according to the problem background in the previous section several protocols have been proposed for underwater sensor networks. These protocols usually rely on the geographical information and exploit greedy policies to optimize the selection of nodes in the next hop. However, the greedy policies are not always feasible and there are still some constraints such as:

1. Vector-based routing protocols are very sensitive to routing pipe radius threshold, which can affect its functioning
2. Some specific nodes on the routing pipe are used to forward data constantly, which can exhaust their battery power so these nodes are suspected to die earlier than the others.
3. All above routing protocols are scalable and robust but they are not energy efficient.
4. If increasing in data packet sending happen, decreasing reception ratio will occur in the reflection of the large packet reception ratio since it causes packet collisions leading to a large number of packets discard.

1.4 Aim of study

The main purpose of our routing protocol is balancing the energy consumption in UWSNs. Whilst sensor nodes have limited energy and the replacement of batteries of underwater sensor nodes can be quite expensive in terms of both time and cost. Energy consumption is really a significant concern in designing routing protocols for the underwater environment.

1.5 Objectives

According to the problem statement this thesis aims:

1. To improve energy efficiency of vector-based routing protocol by enabling multiple sink architecture in 3D UWASNs.
2. To increase the network lifetime with considering the residual energy of each node as well as their position and balance the energy expenditure.

1.6 Scope

The scope of this project is to propose an efficient routing protocol using a multi-sink approach to improve vector based routing protocols. The simulation will be conducted in a 3D environment like the real underwater environment. To verify the effectiveness of the methodology Aqua-sim a NS-2 based network simulator is used. The operation of the proposed protocol will be evaluated in terms of three metrics: energy consumption, end to-end delay, packet delivery rate.

Moreover, this study considers the unique characteristics of underwater sensor networks such as: node mobility, limited energy that is essentially related to the operation of routing protocols. Additionally, this research work will also consider factors which have an effect on an underwater acoustic channel such as: high error probability, limited bandwidth, large propagation delays. However in this work redundancy of the data packet and data security is not considered.

1.7 Significance of Study

This research deploys a new architecture called multiple sink in vector based routing protocol to improve the performance of wireless sensor networks and simultaneously taking remaining of each node into consideration to prolong the network lifetime.

1.8 Dissertation Organization

This report is organized in six chapters as follows: chapter one is an introduction about underwater wireless sensor network and an overview of routing protocols in UWSs, research background, problem statement, objectives, aim, significance and scope of the study. Chapter two will explain about underwater wireless sensor networks in general and literature review. Chapter three will be proposed the design methodology in this project. In chapter four some initial findings and results are defined. In chapter five the final results is presented and also the simulation output graph and discuss over the results to observe how significant our routing protocol performs in underwater wireless sensor networks are explained. At the end in chapter six, conclusion and future work of this study are explained.

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